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STORAGE OF INTEGRATED INFORMATION BY USE OF RANDOM PHASE SHIFT --ETC(U)
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(6) STORAGE OF INTEGRATED INFORMATION BY USE OF RANDOM PHASE SHIFT EQUIPMENT,

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STORAGE OF INTEGRATED INFORMATION BY USE OF RANDOM PHASE SHIFT EQUIPMENT

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ONE

Research into the storage of large amounts of high density, integrated digital and analog laser information is, at present, a relatively lively field of investigation. This research is intimately connected with the modernization of storage and retreival of the information and data in various disciplines, and the subject is receiving a high degree of interest and respect from many people. Normally, people employ a Fourier integrated information diagram as the storage vehicle for integrated information; this practice has the advantages listed below:

(1) As far as the storage and retrieval of large amounts of high density information is concerned, this type of storage exhibits the following five practical characteristics: high durability, high refractive efficiency, high signal to static ratio, high resolution, and good brightness fidelity.

(2) Storage and retrieval equipment is simple; storage and retrieval is fast and convenient, and, with integrated information storage gear, the completeness of information which is stored and retrieved does not suffer from any perceptible influence by such problems as scratches, dust, etc.

(3) Volume storage offers a capability for repeated re-storage of various kinds of information.

(4) Use of the available technology for remanufacturing integrated information plates makes such remanufacture easy, cheap and fast.

The advantages above cannot be compared to microstorage.

In constructing Fourier integrated information diagrams, the following method is used. On a Fourier frequency spectrum, different objects normally give out different information waves and present different frequency spectrum distributions; they normally also give out a set of periodic frequency spectrum distributions - that is to say, on an integrated information diagram, areas where light is concentrated form sharp, bright lines. By the same token, areas where light is very weak appear dark. This makes the light and dark areas unable to be used within the linear areas in which the emulsifier works. Bright lines cause the emulsifier to reach saturation, and, conversely, the dark areas are unable to effectively make use of the emulsifier. This causes the durability, refractive efficiency and fidelity (grey tone level) of the information which is recorded to drop greatly. Initially (1) dispersed focusing was used to correct the problems discussed above, the surface being recorded was taken a section at a time and an accurate Fourier conversion was made on the corresponding area of the integrated information diagram being used for the recording - that is to say, a process of discrete focusing was used. At the present time, the frequency spectrum strength which causes recording to take place on the surface of the integrated information diagram has become relatively even. However, the fact that the distance between discrete focusings must be chosen on the basis of the different information signals received from different kinds of materials, and that this distance must be arrived at experimentally, creates problems with the practical application of this type of technique. Additionally, when the area of the integrated information diagram is increased, the use of discrete focusing causes the durability of the information to decrease.

In order to overcome the problems discussed above, we employed a random phase shift method with a band-sampling net

structure in order to accomplish the storage of large amounts of high density information. (2) The size of the storage area was set by the limits imposed by diffraction; within this area, the energy from the Fourier transformation of frequency spectra for various types of information can achieve an even distribution. Because of this, it is possible to use them within the special curvilinear emulsifier areas in the linear functioning areas of the emulsifiers. Because of this, it is possible to utilize the entire emulsifier area and reach or exceed the requirements for high density, high diffraction efficiency, high resolution capability and high light level fidelity. During the use of random phase shift equipment, we used methods of manufacture which were easy and cheap, and we achieved results in the storage and retrieval of various types of information by the use of random phase shift gear. We also offer for consideration a useful method for the simultaneous storage and retrieval of digital and analog information through integrated information storage.

TWO

The light path involved in the use of random phase shift gear in integrated information is shown in the diagram in Fig. 1. This method utilizes a lens close to the surface of the piece of information to be recorded, and, by the use of this lens arrangement, a Fourier transformation integrated information diagram is made. Light waves from the random phase shift equipment used in conjunction with the band sampling grid net 2 which is in close contact with the information surface to be recorded pass through a Fourier transformation lens. After this, they are divided up by grid-structured, random phase shift equipment into many lines of informational light units based on the random phase shift detected in each unit. After this, a Fourier transformation surface (integrated information surface) can be formed by putting all these bands of light units together.

On a Fourier transform surface, the reoscillation range of light A (ξ), can be described using the equation below [2]:

$$A(\overline{\xi}) = Cr \int \sum_{m=1}^{M} \sum_{n=1}^{N} T(\overline{x} - \overline{a}_{mn}) H(\overline{a}_{mn}) \exp(\phi_{mn}) \exp\left[i\left(\frac{2\pi \overline{x}\,\overline{\xi}}{f\lambda}\right)\right] d\overline{x} \cdots\cdots (1)$$

In this equation $T(\overline{x} - \overline{a}_{mn}) = \begin{cases} 1, & \text{When } |\overline{x} - \overline{a}_{mn}| \leq \frac{l_{mn}}{2} \\ 0, & \text{(under any conditions)} \end{cases}$

$\overline{x}$ is the coordinate vector of the information surface; $\overline{\xi}$ is the coordinate vector of the integrated information diagram surface (that is, the Fourier surface); $\overline{a}_{mn}$ is the coordinate vector for the center of the m and nth grid units selected. l_{mn} is the side-length of the selected grid square; ϕ_{mn} is the random unit phase value of the m and nth grid units. M and N are the horizontal and vertical coordinate numbers taken from the sampling grid; f is the focal length of the lens; λ is the wavelength of the light; Cr is a unitizing factor. $H_{mn}(\bar{a}mn)$ is the difference between unitized brightness and the grey tone levels and uses H_1, $H_2 \ldots H_k$ to represent K of them, then, it is possible to raise them to an undesignated integral. Because of this, the equation above can be rewritten as:

$$A(\overline{\xi}) = Cr \sum_{k=1}^{k} H_k \int \sum_{m=1}^{M} \sum_{n=1}^{N} T(\overline{x} - \overline{a}_{mn}) \exp(\phi_{mn}) \exp\left[-i \frac{2\pi x \xi}{f\lambda}\right] d\overline{x} \quad \cdots\cdots (2)$$

The strength level on the Fourier transformation surface, $I(\overline{\xi})$, is the product of $A(\overline{\xi})$ and its own complex conjugate:

$$I(\overline{\xi}) = A(\overline{\xi}) A^{*}(\xi) \qquad \cdots\cdots (3)$$

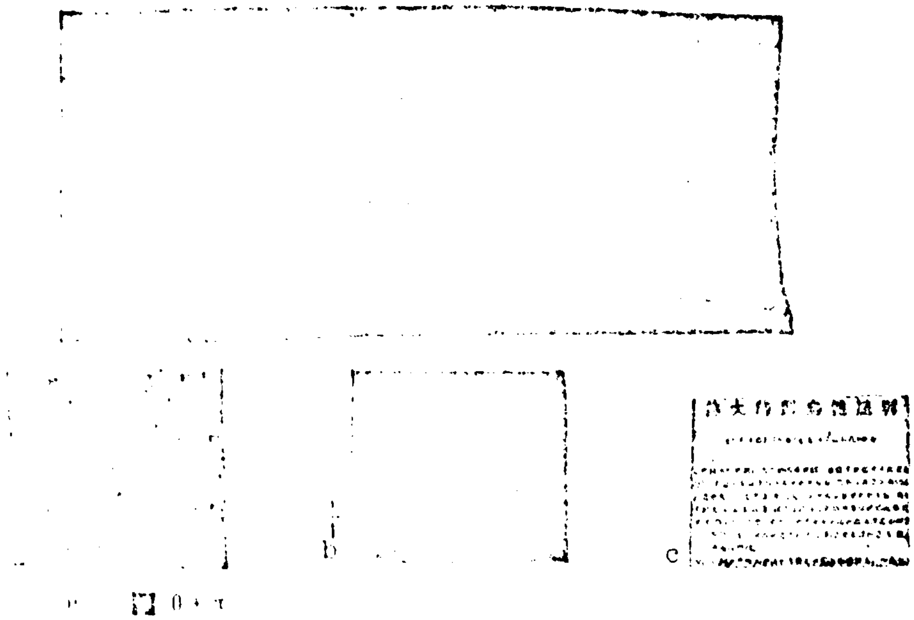


Fig. 1
... ight Path Diagram for Integrated Information Storage ... andom Distribution of Phase Shift Gear (b) Sampling ... (c) Analog Information

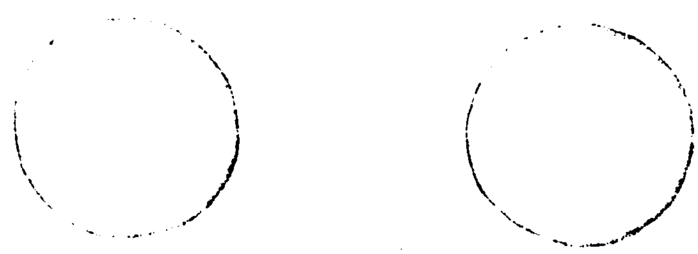


Fig. 2
... Strength Distribution Diagram for Grid Network Frequency ... Which Have Not Passed Through the Phase Shift Gear ... Strength Distribution Diagram for Grid Network Frequency ... Which Have Passed Through the Phase Shift Gear.

According to self-evident physical laws [3], one can ... the value for reoscillation range light strengths, ... The value of the Fourier surface light distribution, ... is in a direct ratio to the value of the Fourier trans- ... strength distribution of individual information ... units on the information surface. Fig 2 (a) gives the

Fourier frequency spectrum distribution for an object on the grid net, but which has not passed through the phase shift gear. This portion of the figure presents a distribution with clear periodic structure. Fig. 2 (b) shows the even distribution of the Fourier frequency spectrum for the same object once it has passed through the phase shift equipment. From this second illustration, it can be clearly seen that the sharp periodic peaks have disappeared.

THREE

Using the light path diagram in Fig. 1, it is possible to form the high density Fourier integrated information diagram for analog information. In tests, the unit area for the random phase shift equipment was a small square hole 32μ on a side. The distance from unit to unit was 40μ, and the units were arranged in a matrix format. Fig. 3 shows a diagram of the random phase shift surface. The differences between the phase position values of each of the various units were 0 and π + 0; the random distribution values for the various units (phase) can be calculated by the use of computers if one uses the Monte-Carlo method.

Fig. 3
Random Phase Shift Equipment Surface Diagram.

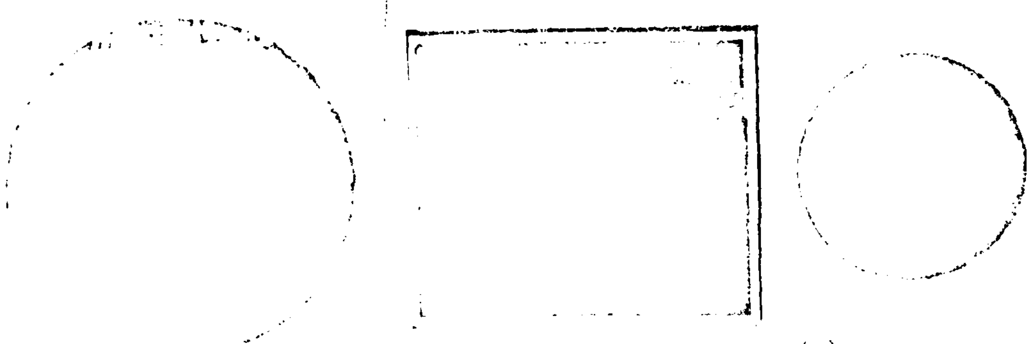
The phase value for each unit is obtained either through a technique employing a photographic emulsifier and calcium

hpochlorite or through a cire perdue kind of photoetching technique. One need only experimentally control the difference between the optical thickness of whitened units and non-whitened units so that it is $\frac{\lambda}{2}$, and one can create the required phase equipment. As far as the emulsifier and calcium hypochlorite are concerned, it is best to try to keep the level of light that penetrates to them and is absorbed by them as low as possible.

When one is using the sampling net and the random phase shift equipment, it is possible to arrange them on the stage of a microscope or a photolithograph machine in such a way that they correspond and overlap their fields. Or, when employing photoetching techniques, it is possible to plate on to the top of the random phase shift gear a layer of metallic aluminum which forms a grid net and which corresponds to the top of that equipment and covers it. In this way, it is possible to combine the random phase shift equipment and the grid network into one unit.

When employing He-Ne lasers as a light source, the power involved is 3mw. An appropriate light strength ratio os selected, and an exposure time of 5" is used. The image is developed using D-19 developer and a development time of approximately 2 sec; the information plates used were Type I plates of Chinese manufacture. As far as the problem of whitening goes, bromine vapor can be used to carry out phase interference whitening.

Figure 4 shows the integrated information diagrams for three types of two-dimensional analog information specimens. Among them, (a) is a specimen of printed text in Chinese characters, (b) is a line diagram or graphic type of information (a resolution test pattern, actually), and (c) is a por-



(a) storage and retrieval of Chinese characters

(b) resolution of test pattern

(c) photograph of a child

Fig. 4

Integrated Information Diagrams, Three Types of Two-Dimensional Analog Information

trait photograph. Fig. 4 (a) shows that the storage and retrieval of Chinese character information was a success; the strokes of the characters in the diagram are clear, and actual measurements of the diffraction efficiency reach 18%. The ratio of average signal power to average static power was greater than 20. The reproduction of the resolution test pattern in Fig 4 (b) is very good; even the finest lines can be clearly made out. The minimum resolution distance between lines was 50μ. The photograph of the small child, which appears in Fig. 4 (c), is reproduced by an orderly arrangement of shades of grey.

FOUR

When using defocusing methods to store different types of information, it is necessary to introduce a small distance between the information surface and the Fourier transform precision back-focus surface (also called the defocusing distance). Moreover, by chosing different defocusing distance values on the basis of experimentation, it is possible to make the frequency spectrum distribution of the distribution on the integrated information plate surface assume an even brightness distribution and without the appearance of sharp peaks in the frequency spectrum. This, in turn, guarantees that the recording medium is able to function in the linear areas in order to bring about high quality reproduction of different types of stored information. However, in actual storage operations. the fact that it is necessary to obtain through experimentation appropriate defocusing distances for different information surfaces turns out, in actual application, to be painstaking and exacting. This lessens the actual practical value of using defocusing methods to carry out the task of information storage.

If random phase shift equipment is employed, the problem of differentiating between different types of information is taken care of, and the whole problem is greatly changed. The Fourier transform frequency spectra for various types of information (character or digital)--after they have been processed through random phase shift equipment--exhibit an excellent averaging of their spectral distribution, causing the frequency spectra distribution for various types of information to be used within the linear range of the recording film. This makes it easy to reduce this information on large area information elements while, at the same time, making it easy to arrange and store various types of digital and analog information. This type of equipment is most particularly significant because it can be used as the integrated information storage equipment for the data bases of high speed, large capacity computers, and perform the functions discussed above for this type of system. It is also a very necessary and important capability of this type of equipment that it can perform the functions discussed above while acting as the high density, full information storage for analog information out of which any [illegible] and information can be searched for and retrieved. Because of this, we recognize that the use of random phase shift equipment for the storage of integrated information is a practical and effective method.

In making the phase shift equipment, because of the restrictions of experimental conditions, control of the phase shift was not precise, and there was usually a certain deviation. The appearance of this type of phase deviation can cause, on the Fourier surface, the appearance of a light level striation pattern. This can cause the diffraction efficiency of the reproduced integrated information to decline, and it can also cause a reduction in the durability of the information storage system. Because of this, precise control of the phase shift value is necessary.

Through the employment of the random phase shift equipment discussed above, we achieved relatively good results in the density of the information stored. On the Fourier surface, the size of the integrated information diagrams also determines the extent of the diffraction striation pattern which is produced in units of information when they pass through an ideal optical system; this area must be kept much smaller than the area of integrated information diagrams used with defocusing methods. In order to raise the density of stored information, it is also possible to employ volume integrated information technology. In this way, it is possible to achieve densities of stored information which are much greater than those which can be achieved by the use of any kind of non-integrated information storage equipment.

As far as the random phase shift gear which we produced for experimentation goes, the techniques and methods for its manufacture were relatively simple. We used this type of equipment to handle many types of analog information, and we have already achieved relatively good storage results. We hope that research work to develop integrated information storage as well as the work of gradually developing practical integrated information storage equipment can be continued in the future.

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